The suburban common frog (*Rana temporaria*) population in the eastern Helsinki suburb, Finland

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The common frog population in the eastern Helsinki suburb was estimated in 1999-2002 by counting the numbers of egg clumps in spawning sites. The study area covered 1590 ha. The frogs were found in various types of green areas such as woodlands, agricultural land and various types of parks. These areas covered 40 % of the whole study area. The population was 786 ± 262 spawning female frogs. The population size increased during the study period. The population density was 1.3 females/ha in green areas. Spawning sites were small dikes, ponds, brooks and their wider parts with still water. Small and shallow dikes and ponds are vulnerable to overfilling and other negative changes. It was found that some new sites were made as a by-product of city works. The amount of spawning habitats seemed to be the density dependent limiting factor controlling the common frog population.

Introduction

It has been repeatedly reported that frog populations are especially sensitive to various types of pollution and habitat destruction. All species are not, however, as sensitive. Several healthy populations have been monitored long enough to verify this (e.g., Meyer et al., 1998). It has been stated that the common frog is less sensitive to urbanisation than many other species (Kuzmin, 1994) and seems to survive in urban conditions (Hitchings & Beebee, 1997).

Frog population studies such as catching and recatching are time consuming. Haapanen (1982) has developed for northern habitats a counting procedure which gives quite exact numbers of spawning female common frogs. The same type of method to estimate the population and to observe the annual variation of a frog population in a long term has been used e.g. by Kutenkov & Panarin (1995). Although males and subadults are ignored, the spawning females are the essential part of the population.

The aim of this study is to count the number of breeding female common frogs and to describe the habitats in suburban conditions in the boreal zone.

STUDY AREA AND METHODS

The common frog populations were surveyed in the eastern part of Helsinki (60°12'N, 25°08'E, 0-25 m above sea level). The study area covers about 1590 ha, which is 8.5 % of the whole area of Helsinki (fig. 1). The area consists of apartment house sectors, small house blocks, industrial areas, and various kinds of traffic lines and green areas (forest, park and meadow in fig. 1). The local industry does not pollute air or waters. The acid rain load has been cut down by 60 % from the situation in the late 1970's (KULMALA et al., 1998). In the late 1980's several lichen species have reinvaded the region showing the enhanced air quality. One apartment house block has been constructed on an old dumping place in the 1970's. In the late 1990's it was found to pollute the soil and small dikes below. According to the information from the City of Helsinki, this pollution is limited to the nearby dikes and does not reach the study area itself.

The constructed areas outside the green areas cannot be regarded significant as a common frog habitat because of high density of traffic lines, the blocking effect of houses on the migration and only minimal green areas. Therefore those areas have not been included in this study as a common frog habitat.

The study area was sparsely inhabited, in some places like countryside, until the 1960's. The rapid urbanisation took place in the 1960's and 1970's, including four-lane road and underground railway constructions. The present green areas appear in the city general plan mostly as parks, outdoor recreation areas and as a university farm. The green areas have been more or less the same during the last 25-30 years. Altogether there are 633 ha green areas, which were divided into 24 sub-areas. These are isolated from each other in most cases by streets, four-lane highways or house blocks.

The green areas are most extensive in the western part of the study area in the university farm, where they form 50 % of all green areas. The green areas altogether cover 40 % of the whole study area but only 25 % east of the university farm (fig. 1).

These green areas were classified into five different habitat types as follows: (1) broad leaved woodlands with rich natural field layer vegetation, later called woodlands, (2) woodland parks, (3) areas covered partly with woodlands and partly well-managed short-cut lawns, called semi-open areas below, (4) agricultural areas; and (5) barren rocky pine woods. The rocky barren woodlands are mostly 20-25 m above sea level, often with fairly steep slopes. The other habitat types are found mostly in lowlands.

There are three brook watershed areas in the study area (fig. 1). The total length of brooks in the study area is 11 km. These brooks have been canalised in earlier times. Parts of them have been restored in recent years. In addition there are small ponds and dikes. Some of the dikes date back to old farming which has ceased decades ago. The few pH measurements in these brooks show that water is close to neutral during the spawning season. The observed pH values are 6.5-7.3 and the water quality in general was good in surveys made by the City of Helsinki (JALAVA, 1987; KETOLA, 1998).

The dikes are very small. The amount of water may be only some cubic metres and most of them are dry later in the summer. Only a small proportion of them have water plants. The

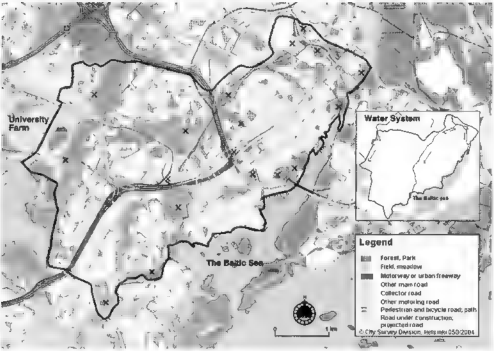

Fig. 1. The study area in the eastern part of the City of Helsinki. X-marked areas show the green areas, where spawning frogs were found. Constructed areas, motorways and other main roads isolate these from each other. Two crosses seem not to be in green areas, but this is not the case. These green areas are either in the corner of an industrial area or above the subway where natural vegetation with a pond has survived. The green areas are not connected to rural areas. The index map shows the brook systems with flowing directions one on the western border, one in the middle and one on the eastern side of the study area.

small ponds are bigger, from 100 to 1000 m², 20-60 cm deep. Many of them are permanent water bodies. Brooks and their wider parts are permanently wet at least in normal years. Only such parts of brooks are used by frogs where there is still water during the spawning season. These brooks are small, 0.5-2 m wide and 20-50 cm deep. Measurements of the flow from one brook were 1.5-1280 l/s, with an average of 35 l/s (KETOLA, 1998). During spawning the flood is mostly over but the flow is apparently above the average.

The study area is connected to the Baltic Sea. The brackish waters are not used as breeding habitat (HAAPANEN, 1982), although the salt content is hardly noticeable. Moreover it varies greatly (0-0.5 ‰), depending on the amount of fresh water and winds.

The spawning sites are of four different types: dikes, small ponds, brooks with still water and the wider parts of brooks with still water.

The counts were made over four years (1999-2002). The year 2002 was exceptionally dry. The amount of rain from early April to mid-June was only 72 mm or 56 % of the long term average. The other years were wet or close to the normal.

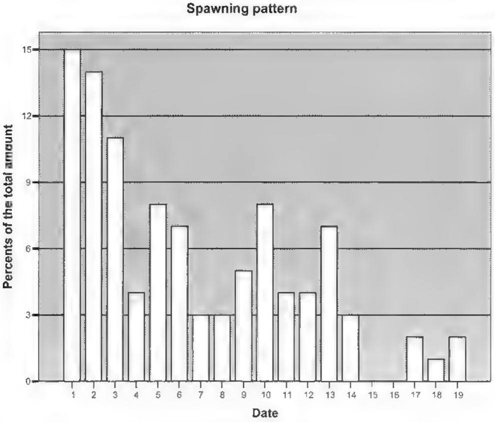

Fig. 2. - The spawning pattern of the common frogs in 2002. The columns show the percentage of egg clumps laid each day (n = 192). The spawning started April 14 and took 19 days.

The census of the common frog population is based on the counting of egg clump masses during the breeding season. One female lays only one egg clump per season (Savage, 1961). The census followed the procedure proposed by Haapanen (1982). This method was developed further, as follows. It is impossible to make the census when all the clumps have to be surveyed at once, as the development starts immediately after laying and accumulations of dozens of egg clumps can occur. However, each day the newly appeared egg clumps can be distinguished and counted in these egg clump groups (Haapanen, 1982). In 2001 and 2002 a certain number of breeding sites were surveyed daily from the early beginning of breeding until no new egg clumps were seen. So it was possible to see which percentage of the total egg clump numbers had been laid each day of the census period (fig. 2).

The spawning sites surveyed daily made a fairly representative sample of the total spawning female population as they formed 10 and 19 % of the total census in 2001 and 2002, respectively. The census in other spawning sites was made approximately after 10 days from the start of egg laying or somewhat later and the numbers were corrected using the correction figure based on the results in areas followed daily (fig. 2). In 1999 and 2000 only one census was made with no additional counting as the method would require (HAAPANEN, 1982). In those two years the figures were corrected based on the results in 2001 and 2002, and by HAAPANEN (1982).

Although the author knows the area very well each year some new breeding sites were found. Especially in 1999 and 2000 the sites were not fully covered. However, most sites were checked each year. The sites surveyed every year (n = 52) covered 57 % of the egg clumps found in 2002. The size of the female spawning population and its annual variation were estimated based on the census figures from the sites surveyed each year 1999-2002.

The results of this study are compared with those obtained in part of this population in 1973-1977 (HAAPANEN, 1982).

RESULTS

SIZE OF THE FEMALE POPULATION

In 1999-2002 there were in average 786 ± 262 (mean and standard deviation) spawning females in the area. The amount of the spawning frog females increased during the whole study period and especially from 1999 to 2000 (fig. 3).

In the university farm the spawning female frog numbers were 81 ± 44 in 1999-2002, versus 58 ± 43 in 1973-1977 (HAAPANEN, 1982). The difference is not, however, significant (P = 0.45, t test).

SUB-AREAS

The spawning sites were found from about 0 to 12.5 m above sea level, but not in brackish waters.

During these four years 91 spawning sites were found on 18 green sub-areas (size 1-125 ha). They covered 70 % of all green areas.

Only one spawning site was found in the small house block in a dike connecting two woodlands. In six green areas no spawning sites were seen. During the study period two sub-areas were lost as spawning area and one additional was found.

The numbers of female frogs varied greatly in these sub-areas. The average number of spawning females in 2002 was 63 ± 70/sub-area (range 3-248). The two sub-areas with 3 and 248 female frogs are located on both sides of a four-lane highway. This big difference in frog numbers was observed in all four years.

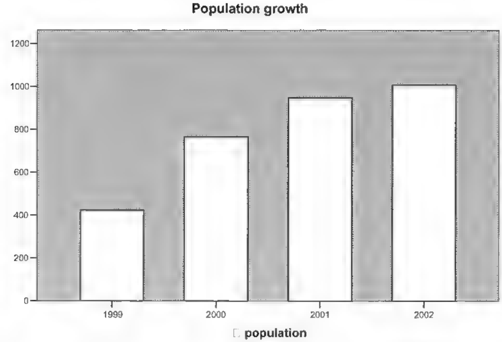

Fig. 3. – The growth of the spawning female common frog population in 1999-2002 in the study area in eastern Helsinki. The figures are the sums found in different sub areas.

There is a strong correlation between the number of egg clumps found in a sub-area and the number of breeding sites (Pearson $r = 0.87$). So the amount of spawning sites accounts for 76 % ($r^2 = 0.76$) of the total variation in the numbers of spawning females between the sub-areas. In contrast, there is only a very low correlation ($r = 0.29$) between the numbers of egg clumps and the size (ha) of the sub-areas. The size of the sub-area accounts for only 8 % of the numbers of the spawning females.

Population density in terrestrial habitats

No frogs were seen to spawn on rocky pine woodland areas although the latter are extensive in the study area and include some ponds. These pine woodlands account 30 % of those green areas where no breeding common frogs were found.

The highest population densities (9.1 and 7.0 female frogs/ha) were found in woodland parks and in woodlands, respectively. In semi-open areas and agricultural land, the densities were much lower (tab. 1). There are only two agricultural areas and these are grouped in tab. 1 with the semi-open areas. In agricultural land there were only 0.8 females/ha.

The spawning female frog density for the whole green area was 1.3/ha and in the whole study area it was 0.5/ha.

The spawning site density was so high (tab. 1) that the frogs could easily reach these sites in any type of habitat and vice versa.

SPAWNING SITES

The most common spawning site in the study area was the small dikes (tab. 2). One half of all egg clumps were laid in these dikes. All together the egg clumps were distributed within different spawning habitat types as these habitat types were used (tab. 3). The average number of egg clumps per site was almost the same (tab. 3).

Only 17 % of the spawning sites were used in every four years. In such areas the egg clump numbers were, however, high in each year (average 31 ± 27) and there is highly significant difference ($P < 0.001$, t test), with the average number of egg clumps (6 ± 6) in sites used only once or twice but not in following years. From 31 to 58 % of sites were empty. The lowest number of unused sites was found in 2002 when the population density was highest. The population increase did not cause the continuous increase of egg clump numbers per spawning site. The population increase was seen in the increase of the number of used spawning sites (tab. 4). In any spawning site the egg clump numbers varied considerably from year to year.

As the spawning sites are very small water bodies, they may easily become totally dry. A high proportion of all breeding sites became dry in early June 2002 when the metamorphosis of larvae had not yet taken place (tab. 5). There were no significant differences between the desiccation of dikes and ponds. All the brooks stayed watered. Some days after the inventory it rained so much that it is quite probable that the larvae in all remaining sites were able to metamorphose.

SPAWNING PATTERN AND START OF SPAWNING

The spawning started just after the average day temperature reached above 5°C. The spawning took 19 days in 2002. Most egg clumps were laid during the first days of spawning: half of egg clumps was laid already on the fifth day of spawning (fig. 2), and after ten days 80 % of all egg clumps has been laid, both in 2001 and 2002.

DISCUSSION

POPULATION SIZE AND DENSITY

The present common frog population is most probably the continuation of the former rural population. Taking into account the low survival rate in this species (50 % according to GIBBONS et al., 1984, 40 % according to LOMAN, 1984), the populations of the study area have lived several generations in the present situation of urbanisation.

The spawning sites of the study area are ideal for egg clump counting and the procedure developed gives quite exact figures of spawning female numbers.

Table 1. - Density of spawning females (female frogs/ha) and of spawning sites (sites/10 ha) in 2002 in different habitat types. Semi-open areas cover agricultural areas with woodlands, too. x, mean; s, standard deviation.

	Woodlands	Woodland parks	Semi-open areas
Population density ($x \pm s$)	7 ± 3.8	9.1 ± 1.6	2.1 ± 2.1
Number of areas	7	2	9
Spawning site density	6.8	9.6	1

Table 2. - Distribution of spawning sites ($n = 91$) between different habitat types and destruction and construction of sites in 1999-2002.

	Distribution %	Destruction n	Construction n
Dikes	51	3	0
Ponds	38	1	1
Brooks	7	0	0
Wider parts of brooks	4	0	1
Total	100	4	2

Table 3. - Distribution of spawning sites ($n = 63$) and of egg clumps ($n = 1007$) in 2002 within spawning habitat types, and mean numbers of egg clumps per site. x, mean; s, standard deviation.

	Dikes	Ponds	Brooks	Wider parts of brooks
Distribution of sites (%)	54	32	9	4
Distribution of egg clumps (%)	51	35	9	5
Number of egg clumps ($x \pm s$)	15 ± 15	18 ± 19	14 ± 21	17 ± 11

The frog population density of the study area is much lower than that (50-530 adults/ha) found by LOMAN (1984) in southern Sweden or that (64-80 adults/ha) found by PASANEN et al. (1993) in eastern Finland. Taking into account that, in these Finnish data, there were only 20 % females, the density figures in woodlands and woodland parks were of the same order of magnitude. The biased sex ratio in northern conditions may be caused by the slower development of the females (LOMAN, 1976; GIBBONS et al., 1984).

Table 4. – Spawning in the 52 sites in 1999-2000, mean and median of egg clump numbers per site x, mean, s, standard deviation

	1999	2000	2001	2002
Percentage used as a spawning site (%)	44	42	50	69
Number of egg clumps/site ($x \pm s$)	11 ± 11	20 ± 24	21 ± 26	16 ± 20
Number of egg clumps/site (median)	26	43	43	39

Table 5. Results of the spawning site inventory on 5-10 June 2002 The figures show the sites which still were watered. Total number of sites surveyed: $n = 58$

	Dikes n (%)	Ponds n (%)	Brooks n (%)	Total n (%)
Watered sites	15 (52)	14 (70)	9 (100)	38 (52)
Egg clumps in watered sites	274 (57)	174 (50)	44 (100)	579 (60)

The results show that the common frog has for generations inhabited areas which seem to be quite fragmented and isolated, though frogs disappeared from one sub-area because the spawning sites were filled and the dikes were canalised.

SEPPÄ & LAURILA (1999) estimated that, in the conditions of the Baltic Sea small islands, 32 or more breeding females per island would result in an effective population In my study area, 35 % of the populations in sub-areas were below this limit.

VOS & CHARDON (1998) found that the most decisive factor on the occurrence of the moor frog was the quality of habitat, not the degree of isolation. The data of this study show that small populations can survive at least several decades even close to highways in spite of the traffic mortality and the isolation.

Anuran population sizes vary because of variation in the size of annual cohorts (RYSLR, 1986) This is quite evident in the case of small populations which are dependent on a small amount of spawning sites (see e.g. HAAPANEN, 1982). Here there were 91 different spawning sites available. This clearly levelled the annual population variations. Also in the present data the amount of spawning females in any spawning site varied considerably from year to year.

CONSERVATION REMARKS

In the study area the destruction of the habitat has not been a big problem during the study period (tab. 2) On the other hand some new sites were constructed All the wider parts of brooks are a result of the restoration of a former canalized brook. The future succession of the vegetation will probably enhance these sites further

The slow filling up of shallow dikes and ponds is a natural phenomenon which can destroy a great part of spawning sites in coming years. The city will be informed on the importance of the small water bodies as a frog habitat The general plan provides certain protection of the summer habitat Still the fragmentation of the population and especially the possible habitat loss make the future of the populations uncertain

Limiting factors

This study allows to discuss whether the spawning habitat can be the density dependent factor limiting the common frog populations in these circumstances.

The summer range of these frogs can be measured as it is isolated from the surrounding by buildings and wide traffic lines. The frogs can easily reach the whole available terrestrial habitat as the distance to the spawning sites is not more than 500 m (see also tab. 1).

It was observed that the amount of spawning sites accounted for 76 % of the total variation in the population density. The size of the terrestrial habitat was only of secondary importance. It was also found that the amount of egg clumps per spawning site did not increase with the increase of the total number of egg clumps. Instead, with the increasing population, the number of spawning sites increased. The frogs apparently started to use the sites of secondary quality. So the number of spawning sites will be the ultimate limiting factor in situations when other factors, e.g. climatic conditions, have not caused the local decline of the population.

Résumé

L'étude porte sur la population de grenouilles rousses de la banlieue est de Helsinki, capitale de la Finlande (60°12'N, 25°08'E). La zone étudiée en 1999-2002 couvre 1 590 hectares, soit 8,5 % de la superficie totale de la ville. Elle a été urbanisée surtout dans les annees soixante et soixante-dix, et sa population de grenouilles provient sans doute des grenouilles qui y vivaient avant cette periode. Les grenouilles occupent les espaces verts de la zone. Ceux-ci couvrent un quart de la zone et se divisent en cinq categories : (1) forêts de feuillus, (2) parcs boises, (3) parcs a moitie ouverts avec pelouses entretenues, (4) terres arables; et (5) bois de pins sur terrain rocheux. Dans la catégorie 5 il n'y avait pas de grenouilles. Les espaces verts des quatre premières categories sont divisés par des maisons, des rues et une route à quatre voies en 24 secteurs, dont 18 avaient des grenouilles au moins pendant une des annees d'étude. Les masses d'œufs dans ces 18 secteurs ont ete comptées dix jours après le début du frai ou un peu plus tard. Le résultat obtenu a été corrige par le nombre de masses dans le secteur où l'on a pu suivre le frai jour par jour (fig. 1). Les frayères étaient des petits fosses, étangs, ruisseaux ou parties stagnantes des cours d'eau (tab. 2). La taille moyenne annuelle de la population de grenouilles en frai a ete estimée a 786 (± 262) femelles dans la zone entiere, et le nombre d'animaux a augmente d'année en année (fig. 2). Dans les 18 secteurs où il y avait des grenouilles, leur densité moyenne était de 1,3 femelles par hectare. Celle-ci était la plus grande dans les habitats boisés (tab. 1). Une correlation significative (r = 0,87) a ete constatée entre le nombre de femelles en frai par secteur et le nombre de frayères. La taille du secteur n'est correlée qu'avec 7 du nombre total des femelles en frai. L'accroissement du nombre de frayères utilisees est allé de pair avec l'accroissement de la population de grenouilles, mais le nombre de masses d'œufs par frayere a augmenté moins vite. La conclusion est que c'est le nombre de frayeres qui limite la taille de la population des grenouilles. Quand la population croît, une partie des femelles est obligée de choisir des frayeres suboptimales.

ACKNOWLEDGEMENTS

Mr Kerkko Hakulinen translated the French summary. My wife, Mrs. Marja-Leena Haapanen, M.D., PhD, has helped in various ways of the treatment of the data. I thank the referees and editors for their comments to improve the text. The City of Helsinki has provided the map of the study area.

LITERATURE CITED

GIBBONS, M. M. & MCCARTHY, T.K., 1984. – Growth, maturation and survival of frogs *Rana temporaria* L. *Holarctic Ecology*, **7**: 419-427.

HAAPANEN, A., 1982. – Breeding of the common frog (*Rana temporaria* L.). *Ann. Zool. Fennici*, **19**: 75-79.

HITCHINGS, S. P. & BEEBEE, T. J. K., 1997. – Genetic substructuring as a result of barriers to gene flow in urban *Rana temporaria* (common frog) populations: implications for biodiversity conservation. *Heredity*, **79**: 117-127.

JALAVA, H., 1987. – [The brooks of Helsinki]. *Helsingin kaupungin ympäristönsuojelulautakunta julkaisu*, **5**: 1-92. [In Finnish].

KETOLA, T., 1998. – [The quality of water and the transport of material in Mellunkyla brook, Eastern Helsinki]. *Helsingin kaupungin ympäristökeskuksen julkaisuja*, **7**: 1-46. [In Finnish].

KULMALA, A., LEINONEN, L., RUOHO-AIROLA, T., SALMI, T. & WALDÉN, J., 1998. – *Air quality trends in Finland*. Helsinki, Finnish Meteorological Institute, Air Quality Measurements: 1-91.

KUTENKOV, A. P. & PANARIN, A. E., 1995. – Ecology and status of populations of the common frog (*Rana temporaria*) and the moor frog (*Rana arvalis*) in Northwestern Russia with notes on their distribution in Fennoscandia. *In*: S. L. KUZMIN, C. K. DODD, Jr & M. M. PIKULIK (ed.), *Amphibian population in Commonwealth of Independent States. Current status and declines*, Moscow, Pensoft Publ.: 64-70.

KUZMIN, S. L., 1994. – The problem of declining amphibian populations in the Commonwealth of Independent States and adjacent territories. *Alytes*, **12** (3): 123-134.

LOMAN, J., 1976. – Fluctuations between years in density of *Rana arvalis* and *Rana temporaria*. *Norw. J. Zool.*, **24**: 232-233.

----- 1984. – Density and survival of *Rana arvalis* and *Rana temporaria*. *Alytes*, **3**: 125-134.

MEYER, A. H., SCHMIDT, B. R. & GROSSENBACHER, K., 1998. – Analysis of three amphibian population with quarter-century long time-series. *Proc. r. Soc. London*, (B), **265**: 522-528.

PASANEN, S., OLKINUORA, P. & SORJONEN, J., 1993. – Summertime population density of *Rana temporaria* in a Finnish coniferous forest. *Alytes*, **11**: 155-163.

SAVAGE, R. M., 1961. – *The ecology and life history of the common frog*, Rana temporaria temporaria. London: 1-221.

SEPPA, P. & LAURILA, A., 1999. – Genetic structure of island populations of the anurans *Rana temporaria* and *Bufo bufo*. *Heredity*, **82**: 309-317.

VOS, C. C. & CHARDON, J. P., 1998. – Effects of habitat fragmentation and road density on the distribution pattern of the moor frog, *Rana arvalis*. *J. appl. Ecol.*, **35**: 44-56.

Corresponding editors: Thierry LODÉ & Alain DUBOIS.